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INFRARED PHOTODETECTOR SPEED TRAP SYSTEM

MOHAMAD AMIR IMRAN BIN MOHD HASLI

A report submitted in partial fulfillment of the

requirements for the award of the degree of

Bachelor of Engineering (Electrical-Telecommunication)

Faculty of Electrical Engineering

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I declare that this report entitled *"Infrared Photo Detector Speed Trap System"* is a result of my own research except as cited in the references. The report has not been accepted for any degree and is concurrently submitted in candidature of any other degree.

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FOR MY LOVELY MOTHER AND FATHER

AND

FOR ALL MY FAMILY, MEMBERS AND FRIENDS

FOR ALL YOUR SUPPORTS, ENCOURAGEMENT AND BEST WISHES FOR ME

ACKNOWLEDGEMENT

First of all, all praises to Allah (S.W.T.), we seek for His help, His guidance and His forgiveness. We ask Him to protect us from bad attitude and to protect us from any bad things. Who He gives His guidances, they will not be deviated, and who had been deviated, they will never get His guidance.

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May Allah Bless All of You.

ABSTRACT

Nowadays, police departments use radar to track and control traffic flow in the road. In addition, metal objects make excellent radar reflector, sending microwaves to receiver before the patrol car come to capture the guilty driver. However, there are numbers of errors that radar always does, make it as an inaccurate instrument for speed trap system purpose. For example, because of its property that travels in straight line, radar cannot detect moving vehicle accurately in curves or hills road. Besides, there could also a chance for vehicle interference to occur. For these reasons, infrared photodetector speed trap system was implemented. The scope of this project is focusing on single moving vehicle at a time. The idea is a pair of infrared photodetector separated in a fixed distance will detect the moving vehicle pass through it and send signal to start and stop the timer circuit. Using the time obtained, system will calculate the vehicle velocity. It is believed that, by using infrared photodetector, the application of speed trap system will be easier since in works on all types of road and surface. By the end of this project, police departments will be able to detect and track guilty driver accurately.

ABSTRAK

Dewasa ini, pihak polis menggunakan sistem radar untuk menjejaki dan mengawal keadaan trafik di jalan raya. Tambahan pula, bahan logam pada permukaan kenderaan menjadi pemantul gelombang yang baik kepada penerima sistem radar, memudahkan polis mengesan pesalah jalan raya. Walaubagaimanapun, terdapat beberapa kesilapan lazim yang berlaku semasa penggunaan sistem radar, menjadikan ia tidak tepat untuk digunakan dalam sistem perangkap halaju. Sebagai contoh, disebabkan sifat gelombang yang bergerak lurus, radar tidak dapat mengesan dengan tepat kenderaan di kawasan jalan raya berbukit atau lencong. Di samping itu, terdapat kebarangkalian untuk pintasan kenderaan berlaku. Atas sebab ini, system perangkap halaju infra merah dibangunkan. Ruang lingkup projek ini terhad kepada satu kenderaan pada satu masa. Sistem ini terdiri dari sepasang pengesan infra merah yang dipisahkan pada jarak tertentu yang ditetapkan akan mengesan kenderaan yang memintas sinaran ini lalu menghidup serta mematikan litar masa. Dengan menggunakan masa yang diperoleh, sistem ini akan mengira halaju kenderaan tersebut. Sistem ini dipercayai lebih mudah untuk dilaksanakan kerana ia boleh berfungsi di semua jenis permuakaan jalan. Pada akhir projek ini, pihak polis akan dapat mengesan dan menghukum pesalah jalan raya dengan lebih tepat dan efisyen.

TABLE OF CONTENT

CHAPTER	TITLE	PAGE
	TITLE PAGE	i
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENT	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF ABBREVIATION	xiii
	LIST OF APPENDICES	xiv
1	**INTRODUCTION**	1
	1.1 Introduction	1
	1.2 Project Objective	2
	1.3 Technical Issue	2

	1.4 Scope of the Project	3
	1.5 Background	4
	1.5.1 Previous Version of Speed Trap System	4
	1.5.2 The Alternative	4
	1.6 Report Overview	5
	1.7 Summary	5
2	**LITERATURE REVIEW**	6
	2.1 Introduction	6
	2.2 Detection System	8
	2.3 Timing System	11
	2.4 Calculation System	11
	2.5 Previous Speed Trap System	12
	2.5.1 Pacing Method	12
	2.5.2 VASCAR Method	13
	2.5.3 Aircraft Method	14
	2.5.4 Hoses Method	15
	2.5.6 Orbis Method	15
	2.5.7 Traffic Radar	16
	2.6 Conclusion	17
3	**METHODOLOGY**	18
	3.1 Introduction	18
	3.2 Work Flow of The Project	18
	3.3 Related Theoretical and Technology	20
	3.3.1 The Infrared	20
	3.3.2 The Photo Detector	22
	3.4 Design of Detection System	23
	3.5 Timing System Development	25

	3.5.1 The Microcontroller	26
	3.5.2 The SK40-C and UIC00A	28
	3.5.3 LCD Monitor 16x2 dot matrix	31
	3.5.4 The Software	32
	3.5.4.1 MPLAB IDE	34
	3.5.4.2 PIC KIT^2	35
	3.6 Calculation System	37
4	**RESULTS AND ANAALYSIS**	38
	4.1 Introduction	38
	4.2 The Sensor Test	39
	4.3 The Stopwatch and Calculation Test	41
	4.4 Analysis of The Result	42
	4.4.1 The Oscillator	43
	4.4.2 The Calculation Process	43
5	**CONCLUSION AND RECOMMENDATION**	45
	5.1 Introduction	45
	5.2 Conclusion	46
	5.3 Future Recommendation	46
REFERENCES		47
Appendices A-B		49-55

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Types of Infrared Radiation Soutces	8

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Typical Infrared Radiation Detection System	2
2.1	Block Diagram of the Project	7
2.2	LED Infrared	9
2.3	Infrared Receiver	10
2.4	Relationship Between Maximum Transmission Range and Radiant Intensity of Infrared	10
2.5	Pacing Technique	12
2.6	Aircraft Method	14
2.7	Hoses Method	15
2.8	Orbis Method	16
2.9	Traffic Radar	17
3.1	Project Outline Flow Chart	19
3.2	Infrared Range In Electromagnetic Spectrum	21
3.3	LM324N Pin Diagram	23
3.4	Detection System	24
3.5	Detector Circuit	25
3.6	PIC16F877A	25
3.7	PIC16F877A Pin Diagram	26
3.8	SK40-C Kit Hardware	29
3.9	UIC00A Programmer	30

3.10	16x2 LCD Monitor	31
3.11	Flowchart of Programming	33
3.12	MPLAB IDE Interface	34
3.13	PICkit™ 2 Development Programmer/Debugger	35
4.1	Model of The Speed Trap System	38
4.2	Sensor Test – Before Metal Container is Placed	39
4.3	Sensor Test – After Metal Container was Placed	39
4.4	System Test – First Sensor Detect Car: Stopwatch Start	40
4.5	System Test – Second Sensor Detect Car: Stopwatch Stop	40
4.6	System Test – Calculatiom	41

LIST OF ABBREVIATION

IR	-	Infrared
PD	-	Photo Detector
CD	-	Compact Disc
LCD	-	Liquid Crystal Display
PN	-	p-type and n-type semiconductor
LED	-	Light Emitting Diode
NEP	-	Noise Equivalent Power
PIC	-	Peripheral Interface Controller
XIR	-	Extreme Infrared Region
MHz	-	Mega Hertz
m/s	-	Meter per seconds
GSM	-	Global system for mobile communication

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	C Coding for Infrared Photo Detector Speed Trap System	49
B	Telecommunication Certificate First Runner Up Award	55

CHAPTER 1

INTRODUCTION

This chapter contains general information of this project such as background of the project, problem statement, objectives of this project, scope of the project and thesis organization.

1.1 Introduction

Infrared lies between visible light and microwave portions of the microwave spectrums with wavelength range between 0.7 and 300µm [1]. This characteristic attracts people attention to study further into usefulness of infrared applications. Infrared technology increasingly present in various applications helps people to enabling many difficult tasks in an efficient way. Already commonly used in remote control of television, video and CD player, infrared technology is also being used and developed for detection technology. Because of characteristic of almost everything in the world that gives off heat, infrared beam could detect things accurately. This includes high speed moving object such as ballistic projectile motion and vehicle. Using infrared and photo

detector as a combination will result in an efficient speed trap system in terms of practical implementation and operating cost, since older version system use radar and antenna to capture the exceeding-speed vehicle [2]. This sound a bit complicated. Plus, the operation cost of the system will be very high if this system is going to be applied in the whole country.

1.2 Project Objectives

In this research, we will apply infrared detector technology in the field of detecting moving vehicle. For this purpose, we will record time taken for a vehicle that passing through couple of infrared photo detector separated apart by a fixed distance. After that, we will measure velocity of the vehicle and display it using LCD panel.

1.3 Technical Issue

Using infrared detector as an alternative for radar based system in speed tracking application will upgrade the older version into newly efficient one. Problems such as antenna positioning error, look-past error, vehicle interference error double bounce error could be solved simply [2]. Basically, a typical system in detecting infrared radiation is usually configured as below:

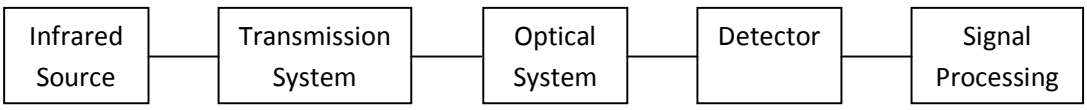

Figure 1.1 Detection of Infrared Radiation

As for infrared source, because all objects with an absolute temperature over 0 K radiate infrared energy, process of detecting vehicle will be difficult. In addition, transmission system of the infrared will influence how well the beam attenuate. So we have to choose suitable infrared radiation source so that the impact of absorption and scattering on the transmission source is minimum. The optical system will focus or converge infrared radiation so that there is minimum loss of energy when passing through atmosphere (transmission medium). To choose good detector, we will concern on photo sensitivity of the detector, noise equivalent power (NEP) and detectivity (D*). After the detector has done its job, it will send out signal output. However, this signal is quite small and sometime needs to be amplified before further system take part.

1.4 Research Scope

When designing an alternative for radar based speed trap system, a flock of questions pop out and needs to be studied. For examples, how did infrared photo detector speed trap system acknowledge the object that it has to detect is a vehicle or not, what if a bird crosses the first infrared detector and fly away to the sky before crossing second detector? For this project, we will assume that the speed trap system is only going to be used in the highway for single car cases so that we could understand the basic before going into details, regarding using infrared photo detector speed trap system as an alternative for radar based system. As for the further system, we will install a timing system into the detector so that the output signal from detector will trigger the timing system to start measure time of the car before stop the time when the car cross another detector. Appropriate model was used to simplify the system.

1.5 Research Background

Before we discuss the main topic of this research, let study the previous version of speed trap system. Here, we will understand how complicated the previous system is. Plus, the needs of high operation cost and sufficient manpower enforce the world to provide an alternative for the useful system.

1.5.1 Previous version of Speed Trap System [5]

Previous versions of speed trap system include manual detection by police officer. They are hiding somewhere in the strategic location and when there is target car, police officers show up out of nowhere, especially at night with their blue red flashing patrol car. Another version of speed trap involve placement of wires on the roadway, which calculates a driver's speed, and is relayed to the police officer in the vicinity. Modern version of speed trap system use electronic radar detection machines, set up on the strategic places side of the road. This radar will detect speed, record speed of the vehicle and display the speed on the sign attached at a patrol car. However, these previous version of speed trap system has some disadvantages that make it difficult to capture guilty driver accurately.

1.5.2 The Alternative

Over the past two decades, infrared detection has become an attraction to people around the world. Many theoretical and experimental studies have been done to

understand the behavior of infrared radiation in atmosphere. Generally, we call near infrared for wavelength region of 0.75µm to 3µm, middle infrared if wavelength lies on 3µm to 6µm and far infrared when the region of wavelength is from 6µm to 15µm. Wavelength longer than this is sometimes called ultra infrared, but this is not a universal accepted terms [4]. One advantage of infrared over old speed trap system is that it can easily detect object because of almost everything emit heat that is infrared energy.

1.6 Report Overview

A thesis is made up of three main parts namely literature review, methodology and result & analysis. In chapter 2, *Infrared Photodetector Literature Review* I'll present the brief literature review to infrared photo detector system. This includes basic things to know when we want to apply infrared in detection system, and how do I choose suitable detector specifically in speed trap application. Chapter 3 is *Research Methodology*, presents a description of the related theory in details to develop speed trap system model. These include description on the system, circuit model, hardware and software implementation.

1.7 Summary

This is an introductory chapter that defines the objectives and research scope of the project. The research background of the project is explained and thesis structure is highlighted as well. In the following chapters, the research work performed will be reported.

CHAPTER 2

INFRARED PHOTO DETECTOR LITERATURE REVIEW

2.1 Introduction

It is important to have a good detection system because in order to detect high speed car, we have to make sure the transmitted infrared is good enough in terms of its absorption and scattering process. Plus, the output signal produce from source has to be sufficient to trigger the timing system to start measure time taken for the car to cross two detectors separated in fixed distance before this time measurement is used to calculate speed of the car. As stated in chapter 1, basically typical system for detecting infrared radiation includes the sources itself, transmission medium, optical system, photo detector used, and output signal processing.

Initially, to understand the operation of this project, I interpret a case study conducted by Charles E Hardy regarding infrared photo detector for measuring projectile velocity that helps me on my research. He divide his project into two main parts which are measurement and calculation apparatus for measuring the time or a ballistic projectile enters and exits a prescribed course, basically a pair or screens which are spaced apart at a known distance. The course will cause a perturbation or fluctuation in the light intensity level received by one or more photo-optics sensor. This detection is used to calculate the velocity of the ballistic projectile and thus display the calculation to the screens. [6]

As for my project, the process is quite similar to the one's describe above but application of the process will be on straight path of highway road. Generally, my

project will be divided into three main stages which are the detection section, timing system and calculation system. This block diagram will conclude my project concisely.

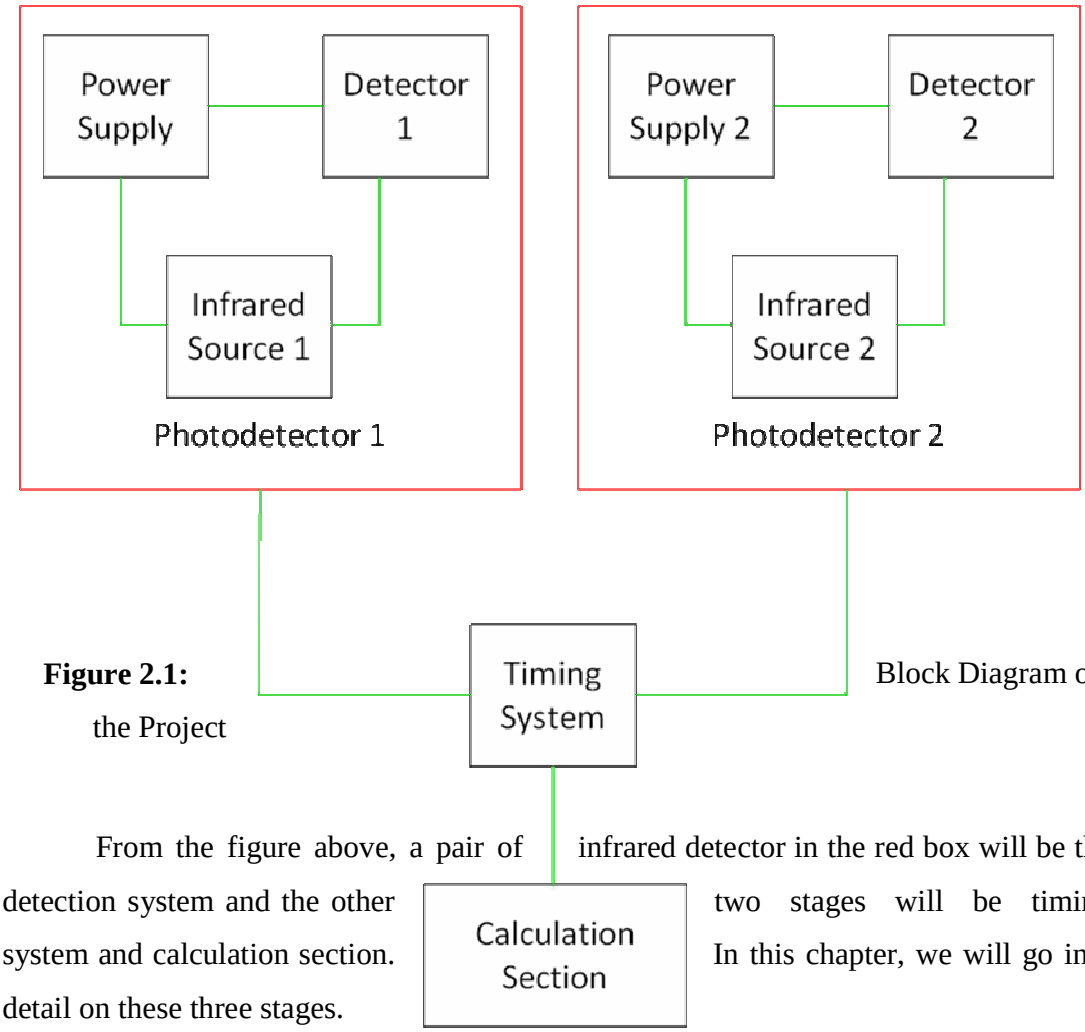

Figure 2.1: Block Diagram of the Project

From the figure above, a pair of infrared detector in the red box will be the detection system and the other two stages will be timing system and calculation section. In this chapter, we will go into detail on these three stages.

2.2 Detection System

Infrared system consists of a pair of infrared sources, photo detectors, and power supply. There are many types of infrared radiation sources, depending on wavelength of the infrared. For example, thermal radiation, cold radiation, and stimulated emission infrared radiation. This table will conclude type of infrared radiation with its corresponding range of wavelength and suitable field of application.

Type	Method	Material	Radiation Source Example	Wavelength (μm)	Remark
Thermal Radiation	Resistor heating by current flow	Tungsten	Infrared Bulb	1 to 2.5	Long wavelength region is cut off by external bulb (glass). Secondary region is emitted through
		Nichrome Kanthal	Electric heater	2 to 5	
		Silicon Carbide (siliconate)	Globar	1 to 50	Constant voltage, large current
		Ceramics	Nernst Glower	1 to 50	Pre heating is
	Secondary Heating by Power Source	Metal (Stainless Steel, etc)	Sheath Heater	4 to 10	
		Ceramic	IRS type lamp	4 to 25	
			Radiant burner	1 to 20	Heating by gas burning
	Heating by Discharge	Carbon	Carbon arc lamp	2 to 25	Causes some environmental problems such as
Cold Radiation	Gas Discharge	Mercury	Mecrcury Lamp	0.8 to 2.5	Long wavelength region is cut off by external bulb
		Cesium			Secondary radiation is emitted through the tube.
		Xenon			
Stimulated Emission	Laser Reaction	Carbon Dioxide	CO_2 Laser	9 to 11	
		Gallium arsenic compound	InGaAsP Laser	1.1 to 1.5	
		Lead compund	PbSnTe Laser	6 to 7	

Table 2.1: Types of Infrared Radiation Sources [3]

Another type of infrared sources is LED Infrared. LED are PN junction devices that give off light radiation when biased in a forward direction. Ideally, the optical source has to be able to transmit at a minimum distance of highway road width. In Malaysia, standard width of highway road is 3.65m [7]. In order to control maximum distance of the transmitted infrared, several factors have to be considered, which are irradiance of the receiver, E_e intensity of the emitter, I_e, NEP and detectivity, D*. A quadratic relationship between the transmission distance and irradiance of the receiver has to be assumed. From the assumption, the maximum distance is calculated as [8]:

$$d_{\min} = \sqrt{\frac{I_e}{E_{e_{\min}}}} \quad (2.1)$$

For my project, since I am only implemented a model of speed trap system, I use LED infrared as the beam source. There are a few advantages of using infrared as the optical sources. The infrared light is not visible to human naked eye. It makes infrared LED perfect enough for sensor application. Compared to laser diode, it is not safe and not convenience to use in short distance sensor application. As for the photo detector, I chose infrared receiver. The reason is because the product was cheap and easy to buy at many electronic component stores. Both infrared LED and photo detector is shown in figures below.

Figure 2.2: Infrared LED

Figure 2.3: infrared Receiver

The transmission range of the optical sources depends on its intensity. Let us look at the curves of radiant intensity vs Transmission range. In this case, we use TSOP4838 IR receiver.

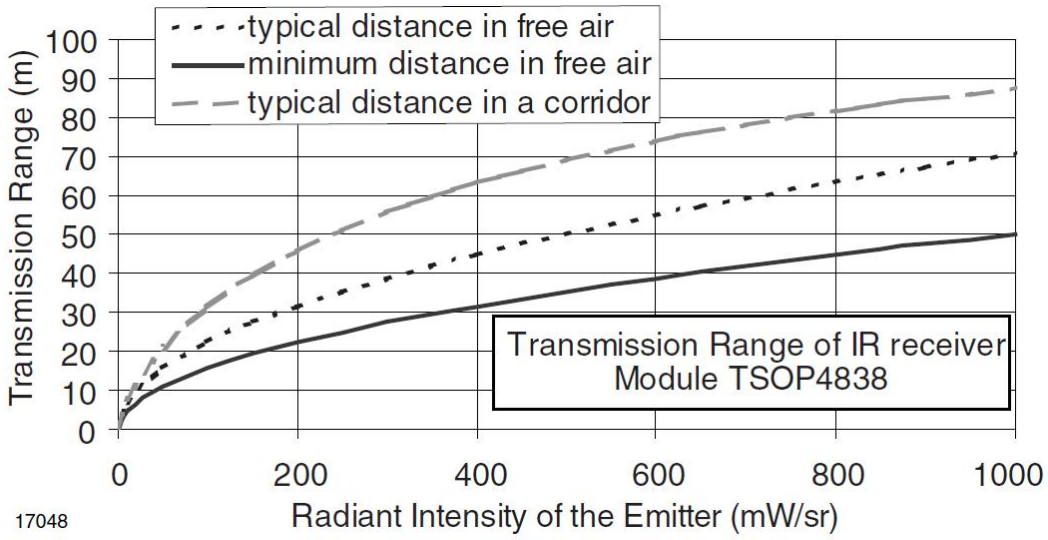

Figure 2.4: Maximum Transmission Range with TSOP4838 as a Function of the Radiant Intensity of the Emitter [8]

Although we have made the assumption that relationship between irradiance and transmission distance does follow a quadratic curve, but in practical, usually this assumption is not fully accurate [8]. However, from the curves, we still could see that with an increasing value of radiant intensity of the emitter, E_e, the transmission distance is also increased.

For power supply, since this is just initial modeling of the system, I use 9V battery for this detector part together with 12V voltage regulator.

2.3 Timing System

After the photo detector receives infrared light, it will send an output signal to timing system. This signal will trigger the timer to start measuring time of the crossing car but before that, the signal need to be converted to digital signal first. There are a number of ways to implement timing system for this purpose. The idea is to use time taken for the car to travel a fixed distance into velocity equation. Signal from the other photo detector will trigger the timer and stop the measurement through appropriate define port. One way is by using LM358 timer chip [10]. This method basically implemented another circuit to be installed with sensor. Another efficient way is to use simple software develop using programming language and load it into PIC. This is what I done. This method is costly effective and easy to troubleshoot. Another advantage of using this technique is power supply could be reduced into one power supply for many function of the system. The timer was then viewed using LCD 16x2.

2.4 Calculation Section

For my project, the calculation part was also done using PIC microcontroller. By controlling the delay, velocity of the car was viewed on LCD 16x2.

2.5 Previous Vehicle Speed Detection [11,12]

As stated above, there are various types of speed trap system implemented to capture guilty driver among the world. This involves classic self tracing method like pacing method and VASCAR method until new technology radar system.

2.5.1 Pacing Method

Pacing method is an old classic method used to estimate velocity of the car. It is done by assigning a police to follow guilty driver by self driving behind the target car. Then, the police officer will estimate speed of target car by looking at speedometer in his car. This method is usually done in night. For easy understanding of the method, consider figure below. It shows how the pacing method works and how to estimate the target car velocity.

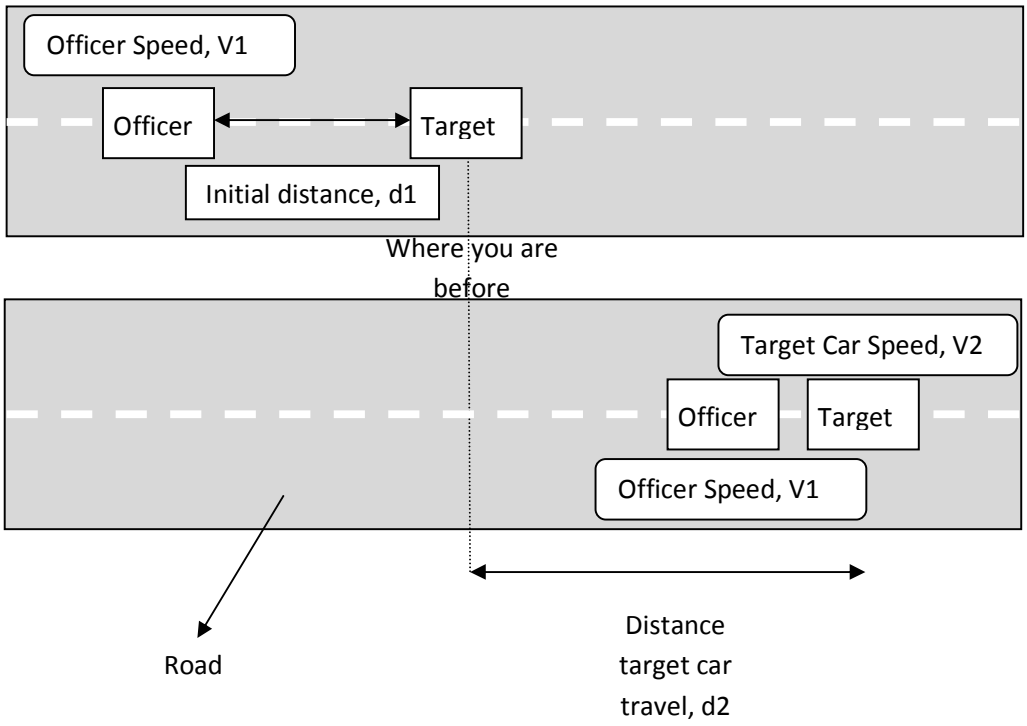

Figure 2.5: Pacing technique

Formula of pacing technique:

$$V_2 = \frac{V_1}{1 + \frac{d_1}{d_2}} \quad (2.2)$$

From above equation, it is concluded that the faster the police car bearing the target, the more distance he will cover over any interval. This method seems to have major disadvantages on accuracy issues. From the formula, we indicate that the farther back the officer, the less accurate the pace. Ideally, to make the pace accurate, the police officer has to maintain distance between patrol car and target car as long as time target car is being paced.

2.5.2 VASCAR Method

VASCAR is an acronym for Visual Average Speed Computer and Recorder. Basically, VASCAR system includes stopwatch and measuring device. In speed trap application, police officer use VASCAR to measure a section of road. When target car enter the corresponding VASCAR covered section, the officer will start the VASCAR switch and stop the switch when the target car leave the section. VASCAR system shows velocity of target car over section of the road.

Despite the systematic approach on VASCAR section, main deficiency of this system is it's depend on the officer who push the switch. In fact, the farther the officer from VASCAR section point, the more probability to occur error since officer's observation from far place is limited.

2.5.3 Aircraft Method

This method is a further improvement of VASCAR method whereas a helicopter is used to push VASCAR switch and speed of the car is determined in the helicopter above the air. When the vehicle passes through the VASCAR section, a radio is used to inform another officer waiting on the side of road. To make the above observer easy to indicate VASCAR section, a mark is placed on the road. The system diagram is shown in figure below.

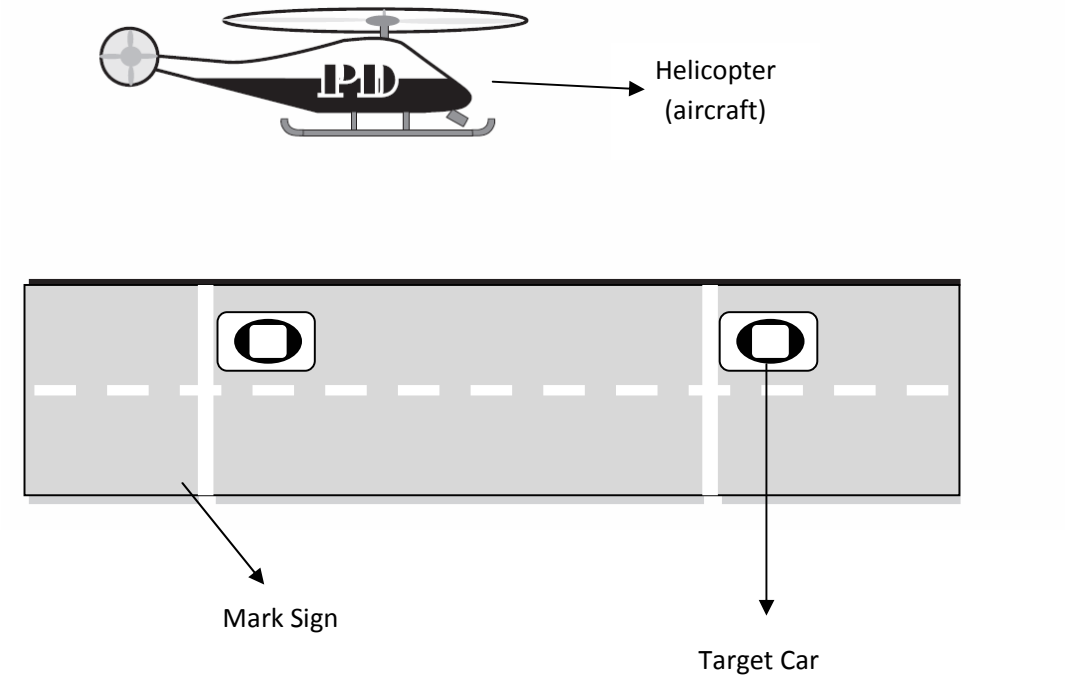

Figure 2.6 : Aircraft method

Despite the further improvement, there are still critical deficiencies in this system. Again, if the officer in the aircraft didn't push the VASCAR button correctly in timing, the estimated velocity is not accurate. Plus, this method is not cost effective, so it's not a good choice to be implemented in the whole country.

2.5.4 Hoses Method

The operation of this system easily understands by look at the figure below.

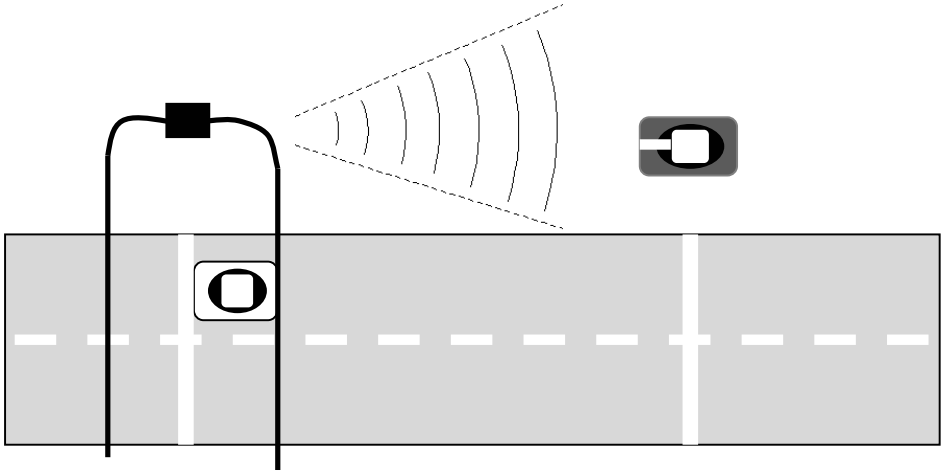

Figure 2.7 : Hoses Method

A rubber hose is placed across the road as the switch to the system. When a car hit the hose, box that contain stopwatch will start measure time until the car hit the other side of the hose. This data was then sent to receiver wirelessly. The speed of vehicle was estimated in the receiver on the police car.

2.5.5 Orbis Method

Orbis come from Greek words which means “eye”. Orbis traffic speed detection systems consist of a capture camera, and rollover sensor in the traffic lane. When a guilty driver which travel faster than preset speed of Orbis, the sensor will trigger

capture camera installed with Orbis to take picture of the car. Details like date, time, and vehicle speed were included together with the picture.

Because of the system that clearly installed in side of the road, guilty driver could easily detect the trap and avoid the system. This will be a major disadvantage of the speed trap system, as we want to catch and reduce numbers of guilty driver nowadays. The graphical picture of the system is as follow:

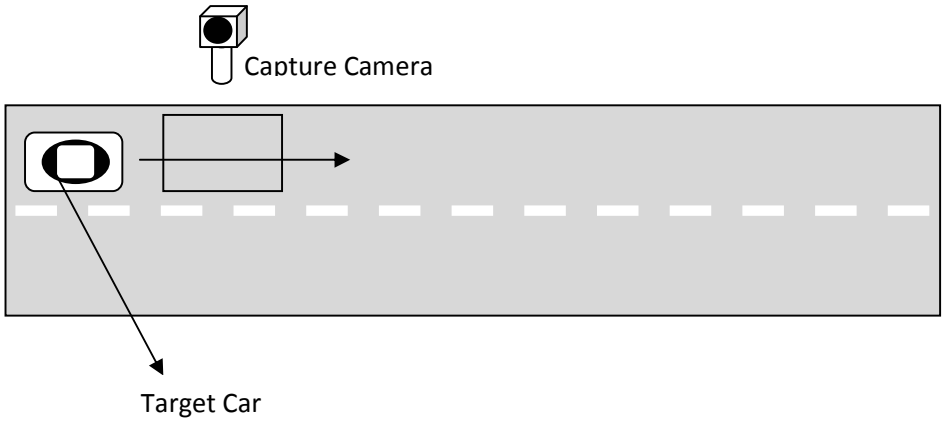

Figure 2.8 : Orbis method

2.5.6 Traffic Radar

Figure below shows briefly about radar system. Basically, radar works like beam of light. They propagate in straight direction. When a vehicle cross the radar beam, it will reflect the beam to the receiver, before further analysis was done. At receiver, they estimate speed of the car by using Doppler Effect. The propagating wave was tuned to a certain frequency at moving vehicle. When the vehicle reflects the wave to receiver, the wave was shifted as outlined by relatively Doppler effects. This new frequency is then used to estimate velocity of the vehicle.

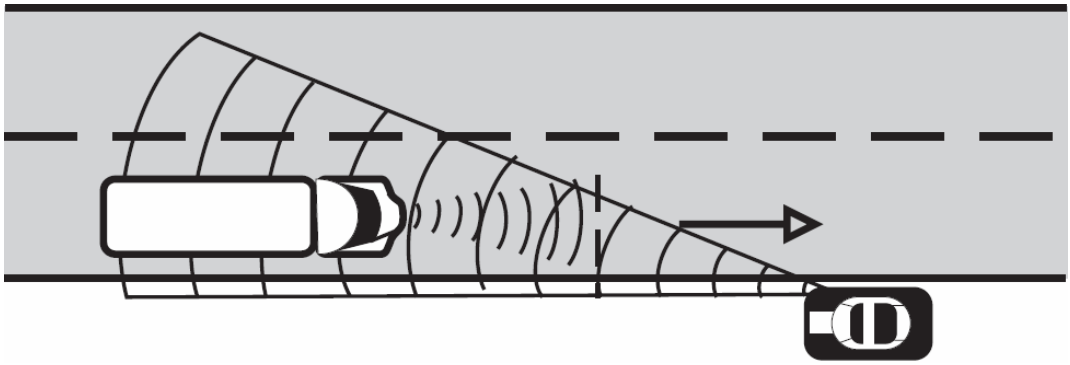

Figure 2.9: Traffic radar.

However, since radar move in straight direction, it comes to problems when radar is used on curves or hills road. This is known as antenna positioning error. Other types of error that radar made are look past error, where radar detect higher size vehicle when dealing with multiple vehicle in straight line, and vehicle interference error, where the estimated speed obtained from detection was not accurate due to interference from other vehicle nearby.

2.6 Conclusion

We have seen the previous version of speed trap system roughly. There are many pros and cons for these systems. Next chapter will discuss in detail about speed trap system using optical source and photo detector receiver, how the system could be an alternative for previous types of speed trap system.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Before this, we have learnt the important concept of the project. In this chapter, we will describe in theoretical how the steps taken to complete this project. This description is based on discussion and research done where it is relevant in terms of time taken to complete the project. Briefly, for this project, there are two main parts to be implemented – hardware which is pair of infrared sensor and stopwatch and programming part which is the instruction to the system. The sensor will generate a voltage rise to trigger the stopwatch circuit and programming will instruct where and when to trigger the circuit.

3.2 Work Flow for the Whole Project

To summarize overall flow of my project, study the flow chart below:

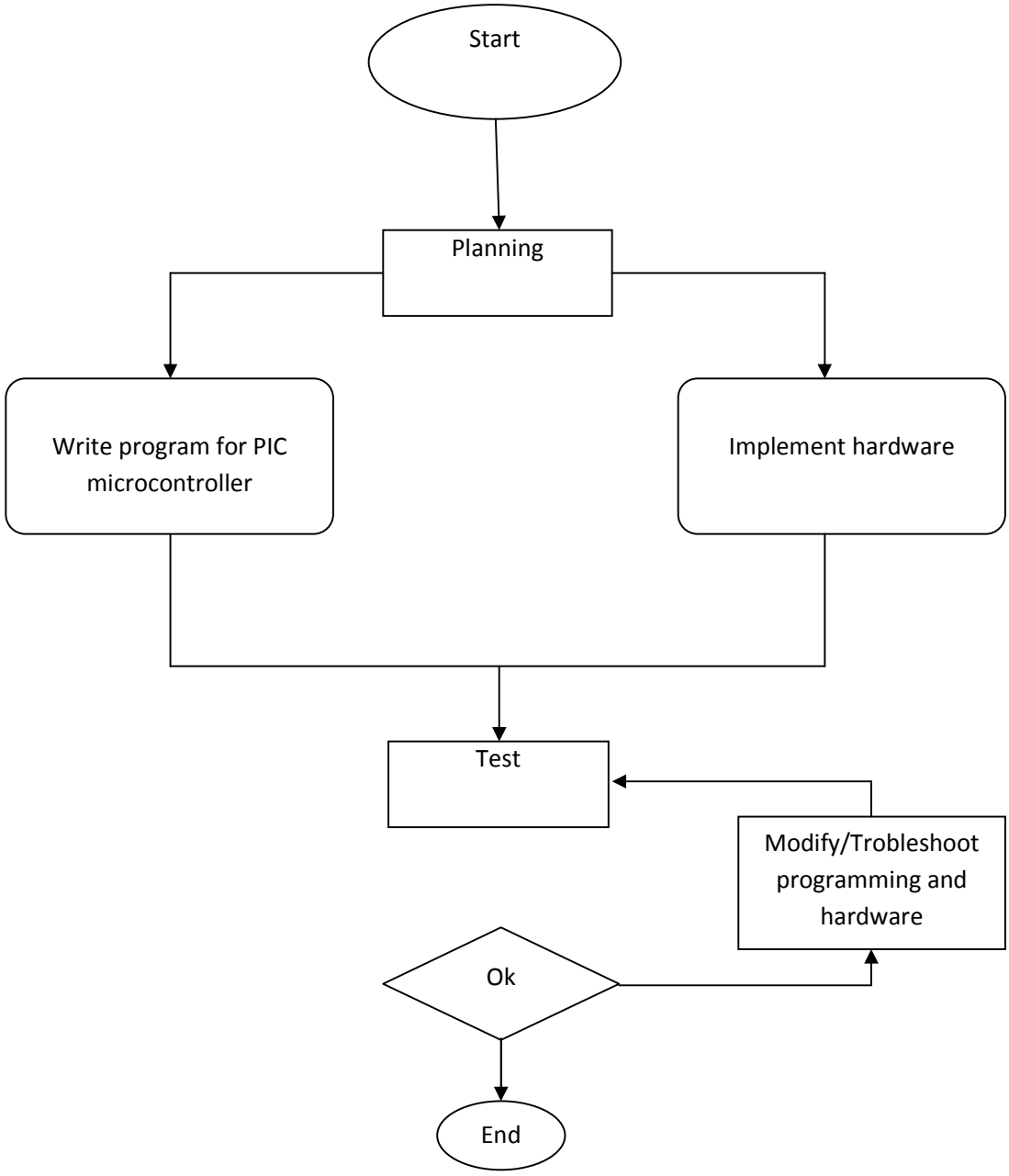

Figure 3.1: Project Outline Flow Chart

3.3 Related Theoretical and Technology

To begin with, before the project was done, I have studied related concept involve in this project, generally the operation of sensor and microcontroller chip. For my project, main resource to study the concept and related theory will be from jurnal, books and course conducted by professional lecturers in UTM. I went through internet and search information relating photonic sensor. However, the scope of photonic sensor is very large. From there I generally identified what is photonic sensor and could be able to do further research. For example, I could identified, what type of source that I want to use, what is the range of source wavelength, what kind of detector to be used an etcetra. I also went through the relevant thesis done by previous graduates in UTM and get some concepts and knowledge to start up my project. From the information I have got, I could design block diagram, related circuit that is being used in my project, and could list down what is the component to be used in the whole project.

Most important theoretical of this project are optical communication. Basic optical system uses light as the primary medium to carry information through a medium to the receiver. This three main things to be considered are optical sources, whether LED or laser diode, propagating medium, which is a platform for light rays to propagate and lastly the photo detector, basically, a device to receive light rays and change it to electrical signal. For my project, the optical sources is infrared LED, air as the medium and infrared receiver as the photo detector.

3.3.1 The Infrared

Infrared lies between visible light and microwave portion in electromagnetic spectrum.

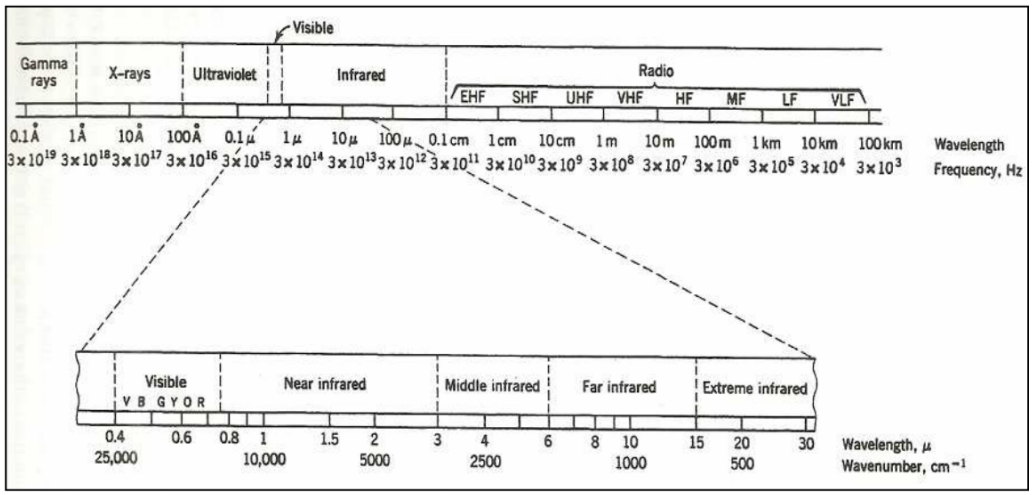

Figure 3.2 : Infrared Range in Electromagnetic Spectrum

From above figure, infrared was divided into four region which are near infrared, middle infrared, far infrared and extreme infrared region. From Hamamitsu datasheet [hamamitsu], it is shown that, the variety of infrared region was useful for many types of applications. The spectral region and nomenclature are actually vary according to the author but these terminology suggested here were following standard teminology suggested by Ballard [14]. Except for extreme infrared region, the first three subdivisions includes region in which the earth's atmosphere is relatively transparent and in XIR, the atmosphere is essentially opaque for paths more than a few meters long [13].

The operation of infrared LED is the same with other light emitting things. Basically, this semiconductor have an active region of minority carrier in opposite type region. Normally empty electron states in conduction band of p type material and normally empty hole states in the valence band of n type material are populated by injected carriers which recombine across the bandgap. This recombine process make these carriers to change their energy state and spontaneously emit photons. [15]

As for this project, operating wavelength (λ_s) of the infrared LED that I've used was 0.94µm which is in near infrared region. This is an important charateristic for optical communication, since λ_s has to be synchronize with spectral range of photo detector. Another important thing to consider is efficiency of infrared LED. Efficiency of optical sources is ratio of number of output photons to number of injected electrons. This means, LED thata emits more photons good optical source for photo detector to detect the light ray.

3.3.2 The Photo Detector

In order for optical communication system to complete, it has to have a detector to convert the optical input into electrical signal before further analysis is done. Performance of an optical communication system is determined here at photodetector.

The operation of photo detector is slightly different to optical source. A photo detector is similar in structure to the p-n junction diode, but the junctions can be exposed to external light, that forming a third optical "terminal". The diode is reverse biased and the electric dield developed across the p-n junction sweeps mobile carriers (holes and electron) to their respective majority sides to create a depletion region. This barrier stop majority carriers crossing the junction in the opposite direction to the field. The field accelerates minority carriers from both sides to the opposite side of the junction, forming the reverse leakage current of the diode. [15]

Important properties of a photo detector is that, it will detect only wavelength less than its cutoff wavelength, λ_c. Efficiency of photo detector was determined by ratio of number of electrons collected to number of incident photon absorbed.

3.4 Designing Detection System

This is the critical part of the project. The detection will detect a speeding car using pair of infrared emitter and photo detector. The needs of this system to deduce what are happening or when to start working is the fundamental of sensor application. It is important to have a good detection system because in order to detect high speed car, we have to make sure the transmitted infrared is good enough in terms of its attenuation and scattering process when it propagate through air. Plus, received power from source has to be sufficient to trigger the timing system to start measure time taken for the car to cross two detectors in fixed distance before this time measurement is used to calculate speed of the car.

The significant component of detection system was voltage comparator. A comparator is electronic components that compares voltage or current and use the larger voltage or currents as the output. For my project, I have used LM324N voltage comparator which has four output pins to be used. However, because of the sensor need to be separated apart, I only used one output pin per sensor. The corresponding pin diagram for LM324N is shown in the figure below:

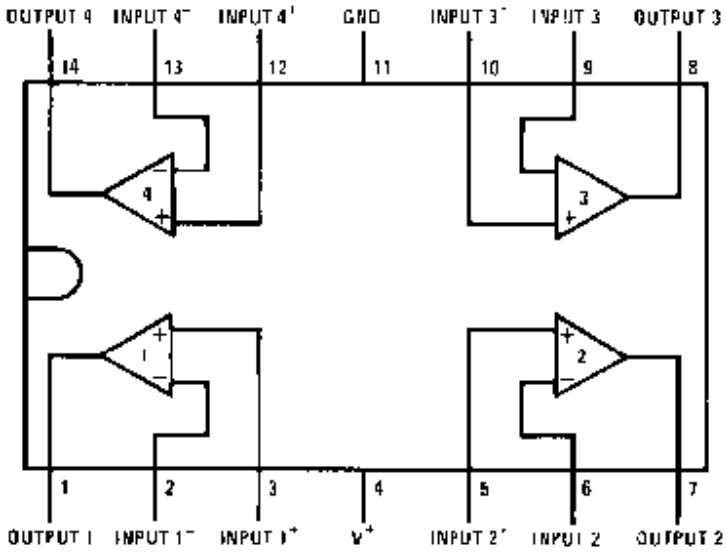

Figure 3.3: Corresponding pin diagram for LM324N

Pin 1, 7, 8 and 14 are the output pins. In designing motion sensor, I was using one of the comparator in this chip and comparing voltage across photo detector and voltage from sensor source as the input 1^+ and input 1^- of the comparator. For easy understanding of operation of detector, consider figure 3.3 and 3.4 below.

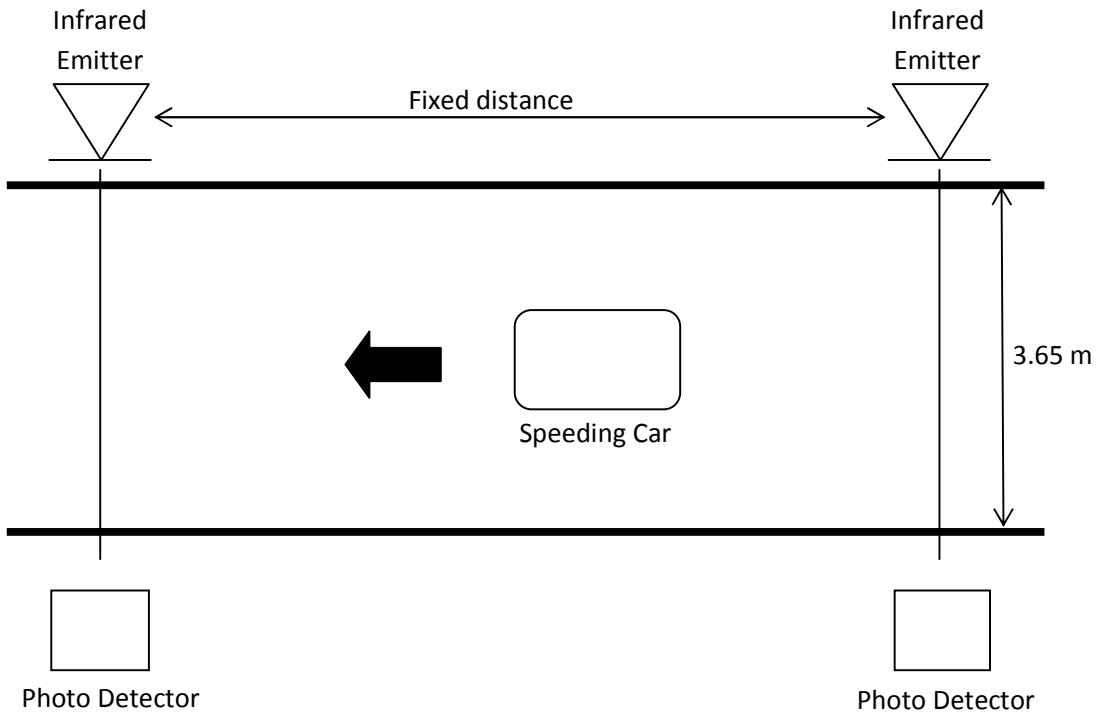

Figure 3.4 : Detection System

From figure above, the value 3.65m is typical value for width of highway road in Malaysia []. When IR light falling on the photo detector is blocked, (i.e. car cross the first sensor), its conductance will decrease and voltage across photo detector will rise. When voltage across photo detector is large enough compared to sensor source voltage, the output of voltage comparator will turn ON and lit the LED. Take note at the connection of input 1^+ and input 1^- of comparator. Because we want the output voltage to trigger the timer when car cross infrared light, we have to connect it in a way that is shown in the circuit diagram below:

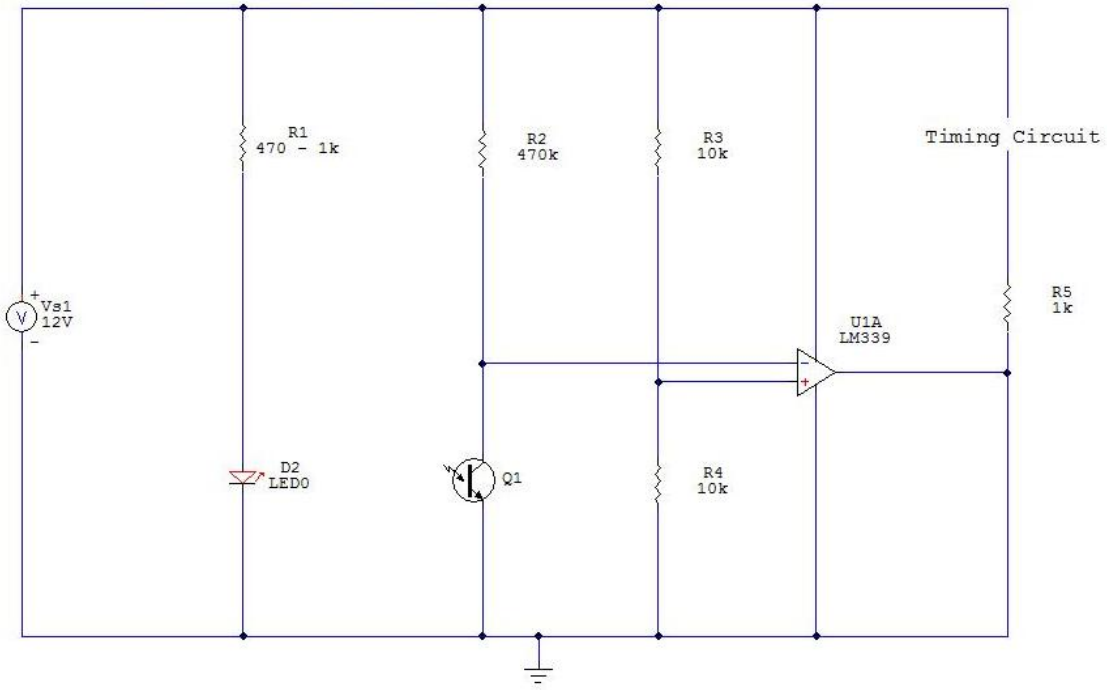

Figure 3.5: The Detector Circuit

The diagram shows that photo detector voltage was connected at input 1^- pin and sensor source voltage was connected to input 1^+ pin. This means, when car cross the sensor, the photo detector was dark i.e. infrared light did not received by photo detector. So, as explained before, this will raise the photo detector voltage and thus lit the LED.

3.5 Timing System Development

There is many ways to implement timing system as explained before in chapter 2. Since I was using PIC microcontroller chip as the main component of the system, it is important to understand the basic operation of microcontroller. Microcontroller is a chip that is designed for embedded application. It stored program in ROM (Read Only Memory) and usually, the program does not change.

3.5.1 The Microcontroller

A microcontroller has several advantages such as low cost and small size. These advantages make it a very popular component in many applications. Below is the Microchip PIC16F877A single PDIP chip.

Figure 3.6: Microchip PIC16F877A single PDIP chip.

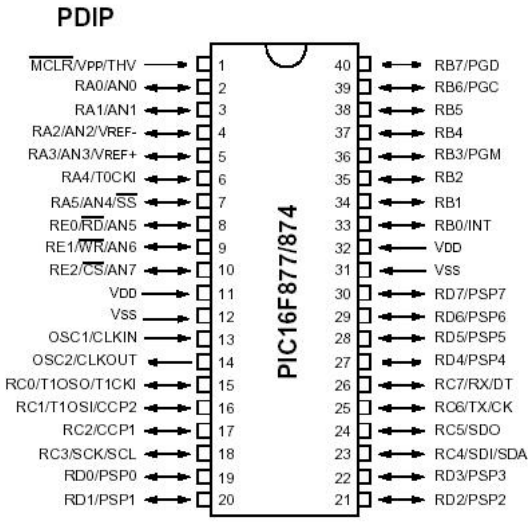

Figure 3.7: PIC16F877A

PIC16F877 is one of the most commonly used microcontrollers in wide range of application involves automotive, industrial, appliances and consumer applications. Figure above shows corresponding pin diagram for this chip. Basically, there are 40 pins which most of it are I/O ports for specific purpose, either general purpose I/O or reserve PIC function. The core features of PIC16F877 are: [16]

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instruction except for program branches which are two cycle
- Operating Speed: DC – 20 MHz clock input DC – 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory.

  Up to 368 x 8 bytes of Data Memory (RAM)

  Up to 256 x 8 bytes of EEPROM Data Memory
- Pin out compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)’
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-Up Timer (OST)

- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor rad/write access to program memory
- Wide operatin voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25mA
- Commercial, Industrial and Extended temperature ranges
- Low power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

For my project, this chip is very important because it could control things based on instruction set by user via programming language. To communicate between programming function and microchip, a programmer has to be used so that

what we instruct PIC to do, we could load it into the chip. There are many types of programmer in the market depend on number of pins PIC have.

3.5.2 The SK40-C and UIC00A

SK40C is another enhanced version of 40 pins PIC microcontroller start up kit. It is designed to offer an easy to start board for PIC microcontroller user. However, all interface and program should be developed by user. This board comes with basic element for user to begin project development. It offer plug and use features. This kit is designed to offer: [17]

- Industrial grade PCB · Every board is being fully tested before shipped to customer
- Compact, powerful, flexible and robust start-up platform
- Suitable for hobbyists and experts
- Save development and soldering time
- No extra components required for the PIC to function
- All 33 I/O pins are nicely labeled to avoid miss-connection by users
- Connector for UIC00A (low cost USB ICSP PIC Programmer) - simple and fast
- method to load program
- Fully compatible with SK40B
- No more frustrated work plugging PIC out and back for re-programming
- Perfectly fit for 40 pins 16F and PIC18F PIC
- With UIC00A, program can be loaded in less than 5 seconds
- More convenient to use and it is smaller than SK40B.

- Maximum current is 1A.
- Dimension: 85mm x 55mm
- SK40C come with additional features:
- 2 x Programmable switch
- 2 x LED indicator
- Turn pin for crystal. User may use others crystal provided.
- LCD display (optional)
- UART communication
- USB on board.
- And all the necessities to eliminate users difficulty in using PIC

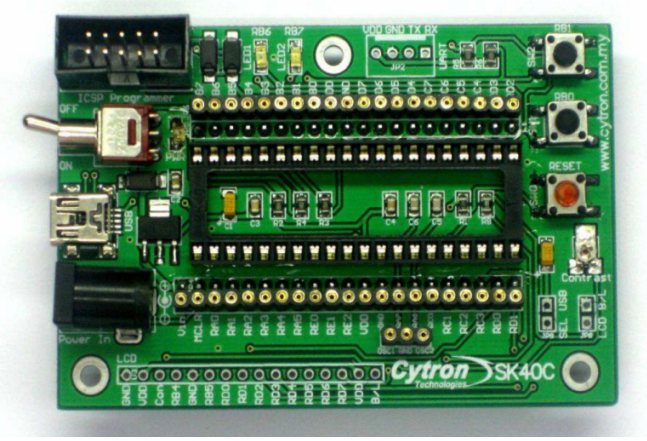

Figure 3.8: SK40-C KIT

This kit was easy to use since it includes basic thing for a newbie PIC programmer. For example, it offers LED and programmable switch, which usually used as an early tutorial for PIC workshops. As explains before, users are able to utilize the function of PIC by directly plugging in the I/O components in whatever way that is

convenient to user. With UIC00A connector on board, user can start developing projects and have fun with this kit right away since the programmer to load program into PIC is build in with this kit.

From the figure, we could see that part of the port in PIC has been set for specific purpose. For example, ports RB0 and RB1 were set to push button while port RB6 and RB7 were set to LED.

UIC00A is the programmer to be used in this project, since it is a low cost programmer and fit with SK40-C kit hardware.

Figure 3.9: UIC00A Programmer

3.5.3 LCD Monitor (16x2 dot matrix)

For instant, we always want a speed trap system to be efficient enough in terms of its function. Thus, for my project, instead of prepare the mechanism for detecting the

guilty driver, I also provide the function to display the velocity of the car that crossed the sensor. This was important function since, for further analysis, we could determined whether this car exceeded speed limit allowed by regulation or not. Figure below shows the LCD monitor and appropriate pin configuration of the LCD.

Figure 3.10: 16x2 LCD monitor

As mentioned before, the SK40-C assigned its port to some function. For LCD monitor, the appropriate port that has been set is port D. However, in writing program, we have to tell PIC that we want to use the port in our program.

3.5.4 The software

Implementation of timing system involves hardware and software works. Before this, I have explained the component involves with this project. Now, I will continue on software part which is like the PIC brain. Computer programming is the process of writing, testing, debugging, troubleshooting, and maintaining the source code of certain computer programs. The source code is written in a programming language either in high level language or in assembly language. The purpose of programming is to create a program that act as instruction to PIC to do something. However, writing a program is not just a simple instruction, we have to use the command prompt of the language to translate our instruction into language that was understood by software.

A lot of available software that can be used to write the program such as Visual Basic, Visual Studio, Micro C, Matlab, Lab View, MPLAB IDE, Bascom AVR and etc. The selection of the software programming must be suit the microcontroller use. For example, Bascom AVR only suitable for the Atmel microcontroller and not suitable for

the PIC microcontroller [tuah]. In this project, MPLAB software adapted with Hitech PICC plugin compiler was used. The reason for choosing this software is simply because it is easy to be used. Adapted with Hi-tech PICC compiler will make MPLAB applicable to understand the C language.

The written program in the MPLAB IDE then will be compiled to produce .hex file format. This .hex file format is a program file that will be used as the timing system for my project. Corresponding instruction that was set could be seen from this flow chart.

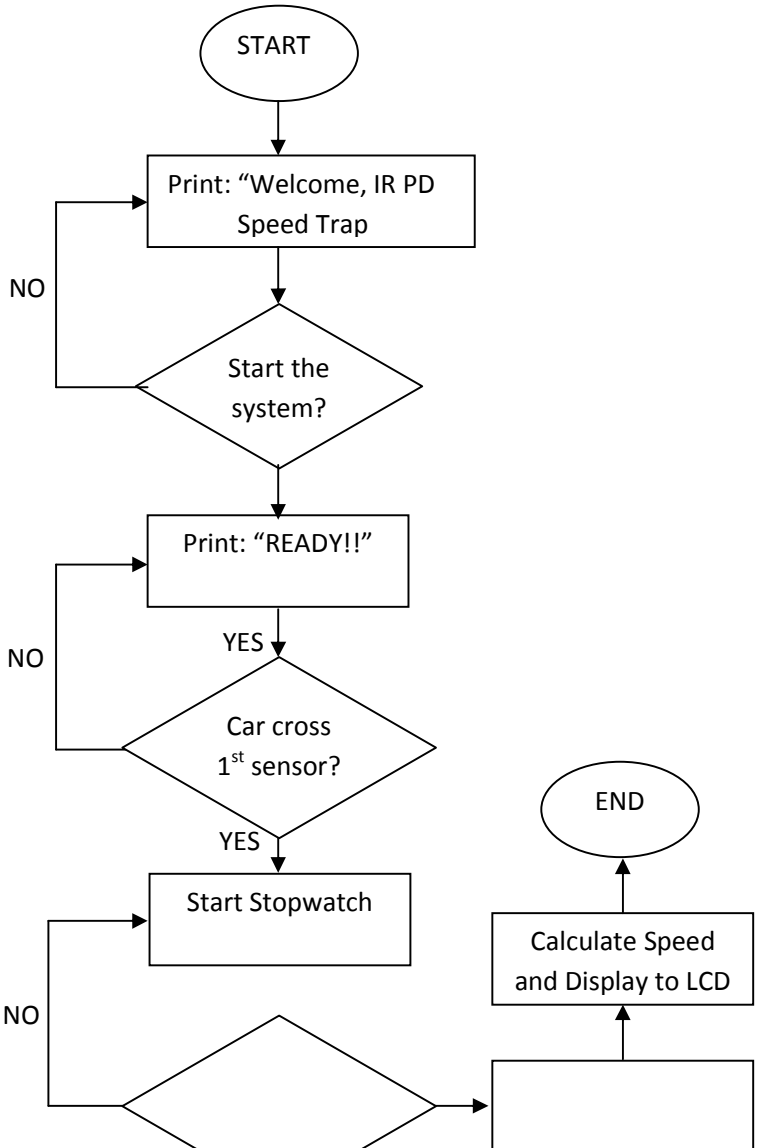

Figure 3.11: Flowchart Of Programming

First, when power supply was provided, the LCD displayed "…Welcome…" and after a certain delay, it displayed "IR PD Speed Trap System". Note that the use of abbreviation was needed since maximum characters that could be displayed by LCD monitor were 16.

Next, the system waits for user to push button so that the system was ready to be used. After that, when the button was pushed, system will display "Ready!!!" at the screen and at the same time, both sensors was ready to capture a car coming towards it.

When a car crossed the first sensor, LCD display will start counting time and stopwatch was displayed at the LCD screen. When the car crossed the second sensor, LCD display will stop the time and display the measured time for a while before display the car's velocity.

To start another measurement, push the reset button and system will start from the beginning again. Note that my speed trap system use push button in its operation. Because of my project was only a model of the system, I have program it to use push button so that easy explanation could be made.

3.5.4.1 MPLAB Integrated Development Environment (IDE)

MPLAB IDE is a free, integrated toolset for the development of embedded applications employing Microchip's PIC microcontrollers. MPLAB IDE runs as a 32-bit application on MS Windows, easy to use and includes a host of free software components for fast application development and super-charged debugging. MPLAB IDE also serves as a single, unified graphical user interface for additional Microchip and third party software and hardware development tools. Moving between tools is a snap, and upgrading from the free software simulator to hardware debug and programming tools is done in a flash because MPLAB IDE has the same user interface for all tools [18].

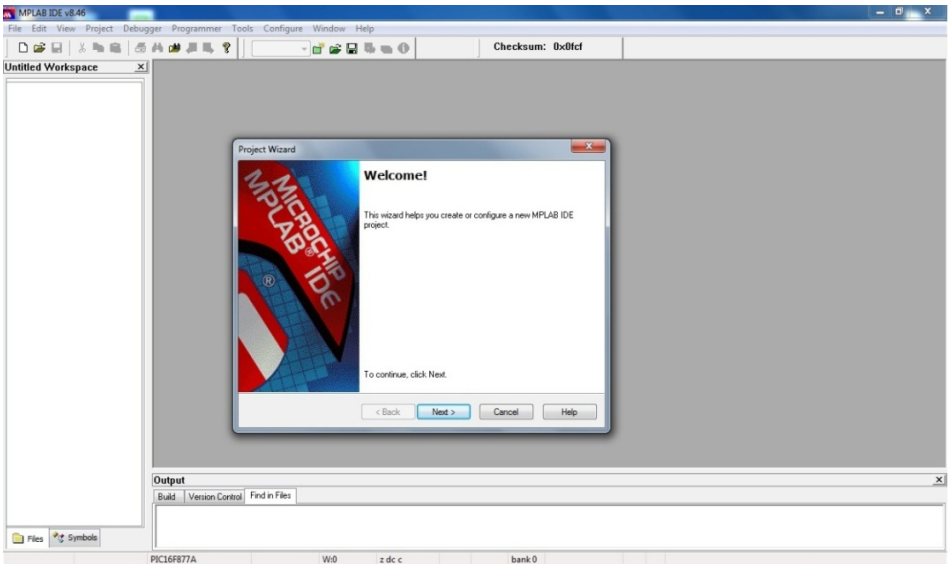

Figure 3.12: MPLAB Integrated Development Environment (IDE) Interface

3.5.4.2 PICkit™ 2

The PICkit™ 2 Development Programmer/Debugger is a low-cost development tool with an easy to use interface for programming and debugging Microchip's Flash families of microcontrollers. The full featured Windows programming interface supports baseline (PIC10F, PIC 12F5xx, PIC16F5xx), midrange (PIC12F6xx, PIC16F), PIC18F, PIC24, dsPIC30, dsPIC33, and PIC32 families of 8-bit, 16-bit, and 32-bit microcontrollers, and many Microchip Serial EEPROM products. With Microchip's powerful MPLAB IDE the PICkit™ 2 enables in-circuit debugging on most PIC microcontrollers. In-Circuit-Debugging runs, halts, and single steps the program while the PIC microcontroller is embedded in the application. When halted at a breakpoint, the file registers can be examined and modified. [19]

Basically, this software was used to load the hex file into PIC by using UIC00A programmer with rainbow cable connected to SK40-C kit. Apart from that, it also can be used to clear the memory in PIC chip, in case of troubleshooting, clearing, or load different types of program into the PIC.

The graphical interface of the PICkit™ 2 software is shown in the figure below. Note that the PICkit™ 2 will display a message to indicate that the device is connected and ready to load the hex file.

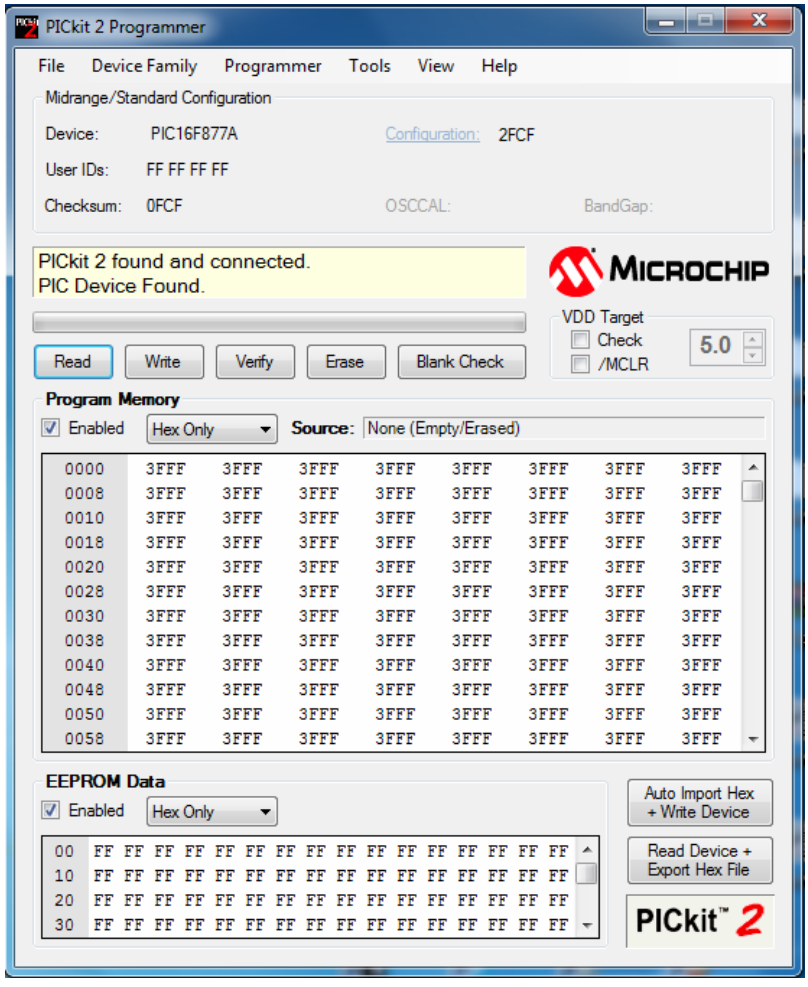
PICkit 2 Programmer
File
Device Family
Programmer
Tools
View
Help
Midrange/Standard Configuration
Device: PIC16F877A
Configuration: 2FCF
User IDs: FF FF FF FF
Checksum: 0FCF
OSCCAL:
BandGap:
PICkit 2 found and connected.
PIC Device Found.
MICROCHIP
VDD Target
Check
/MCLR
5.0
Read
Write
Verify
Erase
Blank Check
Program Memory
Enabled
Hex Only
Source: None (Empty/Erased)
0000 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0008 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0010 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0018 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0020 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0028 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0030 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0038 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0040 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0048 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0050 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
0058 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF 3FFF
EEPROM Data
Enabled
Hex Only
00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
10 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
20 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
30 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
Auto Import Hex + Write Device
Read Device + Export Hex File
PICkit™ 2

Figure 3.13: PICkit™ 2 Development Programmer/Debugger

3.6 Calculation System

Another part of the project is the calculation mechanism. The calculation is basically based on speed equation which takes into consideration distance travel and time taken to travel the distance. For my project, the calculation part was done by program the PIC, since the memory allocated in PIC still sufficient to support this simple calculation.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

Previous chapter described in depth methodology and models used to perform the speed trap system. We now begin with this chapter by present the complete model of speed trap system. As explained in the previous chapter, there are three main parts of the

circuit, which are a pair infrared sensor, SK-40C with PIC16F877A, which includes another two parts that are timing system and calculation mechanism.

Below is the overview of complete models of the speed trap system that are discussing above:

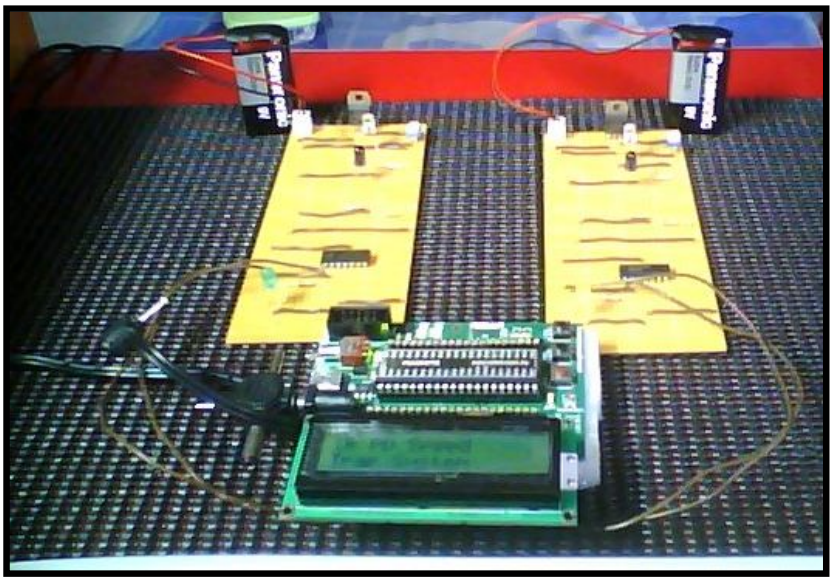

Figure 4.1: The Speed Trap Model

We could see that, there are three sources for two sensors and SK40-C kit. The 9V batteries were connected to 12V voltage regulator.

4.2 The Sensor Test

Figure below shows the complete sensor and how practically the sensor works. Since the system implemented was only a model, I use small metal container to indicate there is a car crossing the sensor. The hypothesis obtained is when a car (metal container) does not cross the sensor, LED is not lit but when the car (metal container) cross the sensor, the LED was lit.

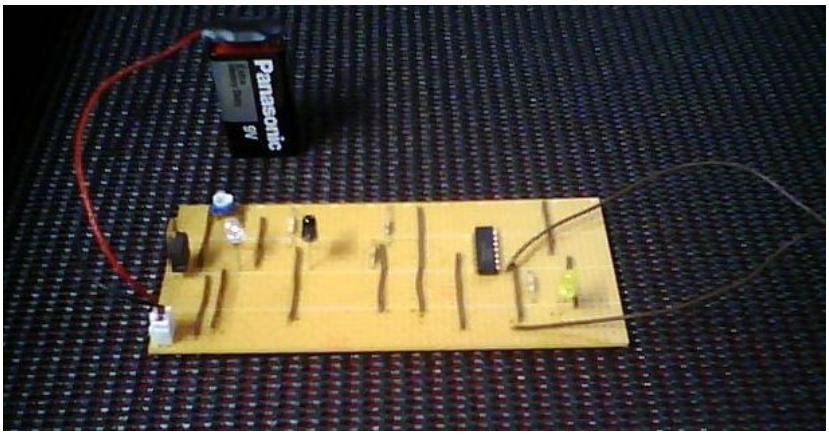

Figure 4.2: Before metal container is placed – LED not lit

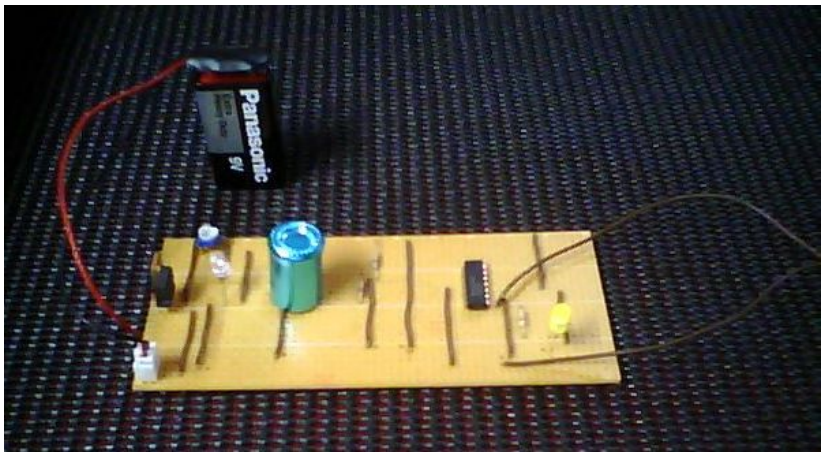

Figure 4.3: After metal container was placed – LED lit

Results obtained shows that the sensor works perfectly in detecting metal container.

4.3 The Stopwatch and Calculation Test

In my project of speed trap system, stopwatch is the timing system used to measure time taken for a car to travel a fixed distance. Figure below shows the results obtained for this project:

Figure 4.4: The car cross first sensor, stopwatch start

Figure 4.5: The car cross second sensor, stopwatch stop

Figure 4.6: After a short delay, LCD display speed of the car

Result shows that the stopwatch and calculation was perfectly working. This could be proved by manually calculating speed using time measured and speed equation which is discuss below.

4.4 Analysis of the Result

From the obtained result, there are several points to be analyzed so that the operation of the project could be understood. This section will discuss important analysis related to result obtained.

4.4.1 The Oscillator

The heartbeat of every microcontroller design is the oscillator circuit. There are two types of oscillator used in microcontroller which is resonant oscillator and crystal oscillator. Most designs that demand precise timing over a wide temperature range use a crystal oscillator. A crystal is a small wafer of high grade quartz cut at certain angle and to a certain size. Thinner cuts will generate higher frequency crystal. Crystals are designed and manufactured to operate at the rated frequency with a certain load capacitance (C_L). Metal leads are plated to the crystal for electrical connections. As a voltage potential is placed across the crystal element, the force of trapped electrons in the crystalline structure tends to deform the element. This is referred to as the

piezoelectric effect. As the element flexes, electrical impedance changes. [20] The crystal acts as an electro-mechanical device and can be modeled as a network of passive electrical components with a very sharp cut off frequency. The physical properties of quartz make it very stable over both time and temperature.

Due to certain limitation of the crystal frequency stability to be generated, the system could not calculate the speed of a very fast car. For SK40-C kit, the crystal used within PIC is 20 MHz [17]. When a very fast car crossed this speed trap system, it shows 0m/s speed which is not accurate.

4.4.2 The Calculation Process

For the calculation, the value displayed on LCD monitor is the result coming from rounding process. As for the stopwatch, I have programmed it to measure up to 1/100 seconds time. However, when it comes to calculation section, I have round it so that it will calculate the real number of time taken. For example, from figure 4.5, the corresponding time taken for that particular case is 15.71 seconds, but speed displayed in figure 4.6 was due to time equal to 15 seconds. So, 1/15 will approximately equal to 0.06 m/s.

CHAPTER 5

CONCLUSION

5.1 Introduction

The infrared photo detector speed trap system could provide possible alternative to the police team and Malaysian Public Works Department (PWD). The easiness of its application in many types of roads give a positive credit to the system compared to radar based method that is used nowadays. However, there are still some technical hurdles to be taken into further research and development of the system. For this chapter, I will list down some recommendation some for future development so that this system could be implemented efficiently in Malaysia.

5.2 Conclusion

The objectives of this project have been successfully achieved. The development of infrared sensor to detect moving car was successful. The timing system to measure time taken of the car to travel a fixed distance was working well according to its operation and limit. Plus, the calculation of the car speed was perfectly works. This project has completed in time and successful as the alternative for previous version of speed trap system. As for my project, I have won the first runner up award for telecommunication exhibition under category optical and photonics.

5.3 Future Recommendation

The system is design to calculate velocity of a car in highway. However, in real practical, most of the cases involved too many cars and vehicle. In the near future, the system could be upgraded to calculate multiple car or different types of vehicles and much more practical cases so that the system could practically be implemented in the country. This could be done using some memory chips and conditional circuit or programming. Another recommendation is that the system works well up to display speed of the car. It will be more efficient if the system could send a message to police department with proper information such as estimated location, time, date and colour of the car. This could be done by implementing another system involve GSM application as the input to PIC microcontroller. In this system, also add another sensor that will detect colour so that the overall system could send precise information to police department.

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21.

APPENDIX A

C Coding – Infrared Photo Detector Speed Trap System

```
//Program For Infrared Photo Detector  Speed Trap System
//Author : Mohamad Amir Imran Bin Mohd Hasli
//4-SET
//Fakulti Kejuruteraan Elektrik
//Universiti Teknologi Malaysia

#include <pic.h>

__CONFIG ( 0x3F32 );//configuration for the  microcontroller

#define rs                      RB4    //RS pin of the LCD display
#define e                       RB5    //E pin of the LCD display
#define lcd_data                PORTD    //LCD 8-bit data PORT
#define button1                 RB0
#define button2                 RB1
#define led1                    RB6
#define led2                    RB7
#define sensor1                 RC1
#define sensor2                 RC2


//global Variables

char i,b;
unsigned char ms        = 0;
unsigned char second    = 0;
unsigned char min       = 0;
unsigned int speed      = 0,a=0;

// function prototype

void delay(unsigned long data);
void send_config(unsigned char data);
void send_char(unsigned char data);
void lcd_goto(unsigned char data);
void lcd_clr(void);
void send_string(const char *s);
void LCD_char_to_no(unsigned char x, unsigned char y, unsigned char
digit_no, unsigned char character);
void LCD_set_DDRAM(unsigned char address);
void LCD_print(const char character);
```

```
void LCD_printxy_string(unsigned char x, unsigned char y, const char
*buffer);
void LCD_print_string(const char *buffer);

// main function
void main()
{

//set I/O input output
TRISB = 0b00000011; //configure PORTB I/O direction
TRISD = 0b00000000; //configure PORTD I/O direction
TRISC = 0b00000110;
PORTB = 0b00000000;
//setup ADC
ADCON1 = 0b00000110; //set ADx pin digital I/O
//configure lcd

send_config(0b00000001); //clear display at lcd
send_config(0b00000010); //lcd return to home
send_config(0b00000110); //entry mode-cursor increase 1
send_config(0b00001100); //display on, cursor off and cursor blink off
send_config(0b00111000); //function set

//display startup message
lcd_clr(); //clear lcd
lcd_goto(3); //set the lcd cursor to location 3
send_string("..Welcome.."); //display "..Welcome.."
delay(200000);
lcd_clr();
lcd_goto(0); //set the lcd cursor to location 3
send_string("IR PD Speed"); //display "IR PD Speed"
lcd_goto(16);
send_string("Trap System"); //display "Trap System"
delay(100000);

      while(1)
      {
            unsigned long n;

            while(1)
            {
                  if(!button1)
                  {break;}
                  else;
            }


            delay(50000);
            lcd_clr();
            lcd_goto(5);
            send_string("READY!");

            while(1)
            {
                  if(!sensor1)
                  {break;}
                  else;
```

```
                }

                lcd_clr();
                ms=0;
                second=0;
                min=0;

                lcd_goto(6);
                send_string(":");
                LCD_char_to_no(10,1,2,ms);
                LCD_char_to_no(7,1,2,second);
                lcd_goto(9);
                send_string(":");
                LCD_char_to_no(4,1,2,min);
                while(sensor2)
                {
                      n++;
                      if(n>=600)
                      {
                            ms++;
                            n=0;
                            LCD_char_to_no(10,1,2,ms);
                      }
                      else if(ms>=100)
                      {
                            if(led1==1)
                            {led1=0;}

                            else if(led1==0)
                            {led1=1;}
                            second++;
                            ms=0;
                            LCD_char_to_no(7,1,2,second);

                      }
                      else if(second>=60)
                      {
                            min++;
                            second=0;
                            LCD_char_to_no(4,1,2,min);
                      }
                }
                led1=led2=1;
                delay(300000);
                lcd_clr();
                delay(50000);
                speed =  100/second;    //change distane

                lcd_goto(0);
                send_string("Speed =");
                LCD_char_to_no(8,1,3,speed);
                lcd_goto(9);
                send_string(".   m/s");
                LCD_char_to_no(10,1,2,speed);
        }
}
```

```
// functions
void delay(unsigned long data) //delay function, the delay time
{ for( ;data>0;data--);           //depend on the given value
}
void send_config(unsigned char data) //send lcd configuration
{
      rs=0; //set lcd to configuration mode
      lcd_data=data; //lcd data port = data
      e=1; //pulse e to confirm the data
      delay(50);
      e=0;
      delay(50);
}
void send_char(unsigned char data) //send lcd character
{
      rs=1; //set lcd to display mode
      lcd_data=data; //lcd data port = data
      e=1; //pulse e to confirm the data
      delay(10);
      e=0;
      delay(10);
}

void lcd_goto(unsigned char data)  //set the location of the lcd cursor
{
      if(data<16)
      {
            send_config(0x80+data);
      }
      else
      {
            data=data-20;
            send_config(0xc0+data);
      }

}
void lcd_clr(void) //clear the lcd
{
      send_config(0x01);
      delay(600);
}
void send_string(const char *s) //send a string to display in the lcd
{
      while (s && *s)send_char (*s++);
}

void LCD_char_to_no(unsigned char x, unsigned char y, unsigned char
digit_no, unsigned char character)
{
      unsigned char ten = 0, hundred = 0;
      if(y == 1)
            LCD_set_DDRAM(x);
      else if(y == 0)
            LCD_set_DDRAM(0x40+x);

      while(character > 99){
            character -= 100;
```

```
            hundred++;
      }

      while(character > 9){
            character -= 10;
            ten++;
      }

      hundred += 0b00110000;              //convert to string binary
      ten += 0b00110000;
      character += 0b00110000;

      if(digit_no > 2)
            LCD_print(hundred);

      if(digit_no > 1)
            LCD_print(ten);

      if(digit_no > 0)
            LCD_print(character);
}

void LCD_print(const char character)
{
      e=1;
      lcd_data=character;

      rs=1;
                                          //write data register
      e=1;
      delay(10);
      e=0;
      delay(100);
}

void LCD_printxy_string(unsigned char x, unsigned char y, const char
*buffer)                                  //max string size is 16
{
      if(y == 1)
                                          //only string no repeating
            send_config(x);
      else if(y == 0)
            send_config(0x40+x);
      else if(y == 3)
            send_config(0x10+x);
      else if(y == 2)
            send_config(0x50+x);

      LCD_print_string(buffer);
}

void LCD_print_string(const char *buffer)//always repeat the string
until the pixels being full
{
      while(*buffer)
            LCD_print(*buffer++);
}
```

```
void LCD_set_DDRAM(unsigned char address)
      //0x00 <= address <= 0x27  display data RAM(DDRAM) is set in t
address counter(AC)
{
      address += 0b10000000;
      //0x40 <= address <= 0x67
      lcd_data=address;
      rs=0;
      e=1;
                              //write instruction register
      delay(10);
      e=0;
      delay(100);
}
```

APPENDIX B

Telecommunication Exhibition Certificate First Runner Up Winner Award

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